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TITLE: CIRCUIT INTEGRITY IN A PACKET-SWITCHED
NETWORK

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CIRCUIT INTEGRITY IN A PACKET-SWITCHED NETWORK

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of priority
5 of U.S. Provisional Patent Application No. 60/147,462, filed
August 6, 1999, and incorporated herein by reference.

The following U.S. Patent Applications, filed
concurrently with this application and assigned to the
assignee of this application, are incorporated herein by
10 reference: (1) ``Communications Using Hybrid Circuit-
Switched and Packet-Switched Networks,' ' [attorney docket
no. 06269-022001 (PA080035)] and (2) ``Bandwidth Management
in a Communications System Using Circuit-Switched and
Packet-Switched Networks,' ' [attorney docket no. 06269-
15 025001 (PA090005)].

BACKGROUND

The invention relates to circuit integrity in a packet-
switched network.

20 System Signal 7 (SS7) messages are often used to
provide control signals in various telecommunications
systems, such as telephone systems, and provide a mechanism,
known as continuity check, for checking the integrity of a
circuit between two switching network endpoints during call
25 setup. Continuity checks originally were developed for
analog facilities and consist, for example, of a frequency
tone transmitted by the originating exchange and looped back

by the receiving exchange. Reception of the returned tone by the originating exchange indicates that the channel is available. In digital environments, use of continuity check operations has been similar.

5 Recently, packet-domain network architectures, such as asynchronous transfer mode (ATM) networks, have been considered for transporting voice and other narrowband traffic. Packet networks allow connections to be made between endpoints without dedicated inter-switch
10 connections. Fixed-size packets of data, known as cells, are transferred between the ATM switches, which are packet switches that provide virtual circuits between the end points of a network.

With the advent of packet voice networks and the
15 introduction of adaptation between circuit-switched and packet-switched bearers, high-quality integrity checks should be capable of detecting and isolating various types of failures. Traditional testing by continuity check tones, however, is incapable of detecting certain failures such as,
20 for example, impaired bits having low significance with respect to a time-domain multiplexed (TDM) sample value. Therefore, better-quality continuity checking suitable to packet networks is desirable.

25 SUMMARY

In general, according to one aspect, techniques for performing a continuity check operation include sending a

pattern of bits over a packet network connection through a first interface on a packet-switched network to a second interface on the packet-switched network. The first interface is monitored for return of the pattern of bits over the packet network connection. A decision whether the continuity check is successful is based on whether the pattern of bits is detected at the first interface during the monitoring.

In various implementations, one or more of the following features may be present. The technique can be used in connection with both narrowband and broadband communications. The continuity check can be performed, for example, during a set-up process for a narrowband call over a packet network. The call set-up process can include sending Signaling System 7 (SS7) messages. The techniques can include providing a loop that connects incoming and outgoing packet streams associated with the packet network connection. The particular pattern of bits may vary depending on various factors including the type of failures to be detected. The pattern of bits can be sent repeatedly over the packet network connection during the monitoring.

A system for performing continuity check operations for traffic that is to be transported over a packet network also is disclosed. The system can include a first gateway that is coupled to a first interface on the packet network and that is configured to execute continuity check operations. The gateway includes a bit pattern generator arranged to

generate a pattern of bits to be sent over a packet network connection, and a bit pattern detector arranged to monitor return of the pattern of bits over the packet network connection. The gateway is configured to decide whether a continuity check is successful based on whether the generated pattern of bits is detected by the bit pattern detector.

The system also can include a second gateway coupled to a second interface on the packet network and configured to provide a loop between incoming and outgoing packet streams associated with the packet network connection. In some implementations, the gateways may be configured to adapt circuit-switched and packet-switched bearers.

Various implementations may include one or more of the following advantages. The techniques described here can help ensure the non-disruptable transfer of data through a packet-switched network. In particular, continuity check operations employing a pattern of bits can be used to test for and isolate a wide range of potential failures that may occur in a packet-domain connection or the adapters terminating the path. Therefore, the continuity checks can help ensure that the circuit will faithfully reproduce the signals traversing it. In some cases, a pattern-based continuity check operation can reduce the number of resources required to execute the test compared to frequency or tone-based continuity check operations.

Other features and advantages will be readily apparent from the following detailed description, the accompanying drawings and the claims.

5 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a telephone connection through a hybrid ATM network and an associated signaling network.

10 FIG. 2 is a simplified block diagram of an exemplary media gateway.

FIGS. 3A and 3B are a flow chart of a method for employing continuity checks in a voice call set up process over an ATM network.

15 FIG. 4 is a signal flow diagram corresponding to FIG. 3.

FIG. 5 illustrates further details for performing a continuity check operation.

FIG. 6 illustrates an exemplary bit pattern.

20 DETAILED DESCRIPTION

As discussed in greater detail below, improved techniques are described for providing continuity check operations to ensure circuit integrity for communications over a packet-switched network. The techniques involve the exchange of a known pattern of bits during call set up processes rather than sending and detecting tones. The

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techniques can be used to test the integrity of the packet circuit and the adapters at either end of the circuit.

The particular examples discussed below involve narrowband traffic such as voice calls, modem data or
5 facsimile data, sent over a packet-switched network. However, continuity checks that include a pattern of bits can be used for broadband communications over a packet-switched network as well.

As shown in FIG. 1, a continuous call path can be
10 established starting with a narrowband Signaling System 7 (SS7) ISDN user part (ISUP) call that originates, for example, in a Public Switched Telephone Network (PSTN) 102A. The path can be established using a virtual circuit over an ATM network 101 and completes on the terminating side in a
15 narrowband circuit-switched SS7 ISUP call to the terminating subscriber through another circuit switched network 102B. A control mechanism interacts with the circuit-switched and packet-switched networks to correlate SS7 and ATM connections to establish a single continuous information
20 path.

A large number of individual telephone circuits, such as DS0 circuits, that are to be connected to the packet network 101 can be carried, for example, on fiber optic carriers 105 using time-division multiplexing (TDM)
25 according to the Telcordia Synchronous Optical Network (SONET) standards. The carriers 105 are coupled to access ports 116 in media gateways 100A, 100B (see FIG. 2).

The media gateways 100A, 100B adapt the TDM telephone line signals to packet-based signals and vice-versa. The TDM telephone signals are circuit-switched, in other words, the bit stream can be divided temporally into individual DS0
5 circuits. By contrast, in packet-based signals, the bit stream can be divided according to the destination address of each packet.

Each gateway 100A, 100B can separate incoming TDM signals into individual DS0 signal streams. In one
10 implementation, shown in FIG. 2, each gateway, such as the gateway 100A, includes a TDM switching matrix 117 that provides full switching capabilities. The switching matrices 117 permit the DS0 circuits to be interconnected flexibly with narrowband channels appearing on the gateways.
15 Echo cancellation and other digital signal processing functions can be performed in a digital signal processing portion 118 of each gateway. The signal processing portion 118 includes a pattern generator 122 and a pattern detector 124 for generating and detecting specified patterns of bits,
20 respectively. The pattern generator 122 and pattern detector 124 can be implemented, for example, using microprocessors, digital signal processors, or custom application specific integrated circuits (ASICs). DS0 signal streams are adapted by an ATM adaptation layer 120
25 into ATM cells. Each cell is inserted through the ATM ports 21 into an ATM cell stream 135 that traverses an ATM network 101. The gateways include a control section 119 that

controls overall operation of the gateway. In one implementation, the gateways 100A, 100B are implemented as Salix 7720 Class-Independent Switches available from Tellabs Operations, Inc.

5 As illustrated in FIG. 1, each gateway 100A, 100B is connected to a respective ATM end point switch 115. The connection between a gateway and an ATM end point switch 115 and the connection between the ATM end point switch and the ATM network 101 are user-network interfaces (UNIs). Within
10 the ATM network 101, there are a number of ATM switches 110 which are interconnected by network-node interfaces (NNIs).

A call control network 126, which forms part of an existing telephone system, runs parallel to the voice network. The call control network 126 primarily controls
15 telephone switching equipment to connect the originating and terminating ends of a telephone call using SS7 messages. A call controller 120A, 120B is coupled to each gateway 100A, 100B and provides an interface between the gateway and the call control network 126. The exchange of call control
20 signals allows the gateways 100A, 100B to establish a connection through the ATM network 101 to enable the transmission of narrowband traffic between the end points.

As shown in FIGS. 3 and 4, to establish a voice connection, a user at the originating end dials 210 a
25 telephone number. A connection is established through an originating TDM circuit switch in the circuit switched network 102A, and the call controller 120A at the

originating end receives 215 an SS7 initial address message (IAM) 150. The call controller 120A routes 220 the call, in other words, it identifies a call controller 120B associated with a terminating DS0 circuit in the circuit switched

5 network 102B. The call controller 120A also determines 225 whether a continuity check operation is to be performed as part of the call set up. A trade-off exists between the desire to perform a continuity check during each call set up and the extra time and overhead associated with performing
10 continuity checks. As a result, typically only a percentage of the call set-ups will include a continuity check operation. In one implementation, approximately 5-10% of call set-ups would include a continuity check operation.

Assuming that the call controller 120A determines that
15 a continuity check operation is to be performed, the call controller sends 230 a connection control message (CreateConn) 152 to the originating gateway 100A to initiate a connection through the ATM network 101. The CreateConn message 152 includes an indication that a sending-side
20 continuity check operation is requested. In response, the gateway 100A reserves 235 resources for the call and makes the pattern generator 122 and pattern detector 124 available. Connections are set up between the adaptation layer 120 and the pattern generator 122 as well as the
25 pattern detector 124. The pattern generator 122 repeatedly generates 240 a specified bit pattern, and the detector 124

monitors 245 the incoming packet stream (if any) for the same bit pattern.

The particular bit pattern used may depend on the application. For example, in one implementation, the pattern generator 122 is programmed to generate a bit pattern such that both binary values in each possible bit position in the packet can be checked. Thus, the pattern generator 122 can generate a sequence of two complementary 8-bit values. Other bit patterns can be generated to allow various types of potential failures to be detected and isolated. Thus, in some implementations, the pattern generator 122 is programmed to generate a bit pattern comprising a sequence of 256 values, in other words, a sequence of all possible 8-bit values. More generally, the pattern generator 122 can be programmed to generate a sequence of all possible n-bit values, where n is the number of bits in each byte.

Another exemplary pattern is illustrated in FIG. 6 and includes twenty 8-bit values. A first byte includes only ``1''s, whereas a second byte includes only ``0''s. The third through tenth bytes include a single binary ``1'' with adjacent bytes differing by shifting the binary ``1'' value from one bit position to an adjacent bit position. Similarly, the eleventh through the eighteenth bytes include a single binary ``0'' with adjacent bytes differing by shifting the binary ``0'' value from one bit position to an adjacent bit position. The nineteenth byte includes an

alternating pattern of ``1''s and ``0''s. The twentieth byte includes the inverse pattern of the nineteenth byte. Other bit patterns may be used depending on the specific errors to be detected. Known error detection/correction techniques
5 may be useful in selecting an appropriate bit pattern for a given application.

After making the pattern generator 122 and detector 124 available, the gateway 100A returns 250 an acknowledgement message (CreateAck) 154 that includes a connection

10 descriptor. The connection descriptor includes an ATM address for the gateway 100A as well as information that uniquely identifies the call. The information that uniquely identifies the call can identify a connection-related resource such as the narrowband circuit (e.g., DS0 circuit)
15 handling the call on the originating side.

Next, the call controller 120A sends 255 an IAM message 156 to the terminating call controller 120B. The message 156 includes the information contained in the connection descriptor as well as an indication that the continuity
20 check operation is to be performed. Upon receiving the IAM message 156, the terminating call controller 120B routes 260 the call. In other words, the terminating call controller 120B selects a TDM circuit on a particular gateway, such as the gateway 100B, to handle the call. The call controller
25 120B then sends 265 a connection control message (CreateConn) 158 to the terminating gateway 100B. The CreateConn message 158 also includes the information

contained in the connection descriptor. In addition, the message 158 includes an indication that the receiving-side of a continuity check operation is being requested.

In response, the terminating gateway 100B establishes
5 270 a packet domain connection 126 with the originating gateway 100A through the packet network 101, as shown in FIG. 5. As part of setting up the packet domain connection, the information that uniquely identifies the call is forwarded through the packet switches 110, 115 until it is
10 received by the originating gateway 100A. That allows the originating gateway 100A to associate the packet-domain connection with the TDM-domain connection for the call. The gateways 100A, 100B and ATM switches 110, 115 negotiate the ATM routing headers that will be used between hops along the
15 packet-domain connection.

The gateway 100B also sets up 275 a continuity check loop between the incoming and outgoing packet streams 128, 130 associated with the packet network connection. FIG. 5 shows the loopback provided in the TDM-domain of the gateway
20 100B. More generally, however, the loopback can be provided in either the TDM-domain or the packet-domain depending on the type of failures the continuity check is intended to detect. A control message (CreateAck) 178 is sent 280 by the terminating gateway 100B to the terminating call
25 controller 120B to acknowledge that the packet-domain connection has been established for the call and that the continuity check loop has been set up. The bit pattern

appears as successive TDM samples in the TDM domain, when the loopback is provided in the TDM domain, and appears within the cell stream in the ATM domain.

As the pattern generator 122 repeatedly generates the specified pattern of bits, the pattern detector 124 monitors the incoming bit patterns and determines (FIG. 3A) whether the incoming pattern matches the bit pattern that was generated by the generator 122. If the packet connection is properly established and if the adaptation functions in the gateways 100A, 100B are operating properly, the specified bit pattern will be detected by the detector 124 after traversing the packet connection 116 and the continuity check loop.

The pattern detector 122 can include a software or hardware timer 132 that provides a timeout function. If the pattern detector 124 does not detect the generated pattern within the time set by the timer 132, the continuity check fails. In that case, the gateway 100A signals the call controller 120A or a management system (not shown) to inform it of the failure. The results of the continuity check operation can be used to determine the cause of the failure.

On the other hand, if the generated pattern is detected within the time set by the timer, then the continuity check is successful. The gateway 100A disconnects the pattern generator 122 to allow a purge operation to be performed so that the pattern of bits is not forwarded to the TDM circuit handling the call. Once the detector 124 no longer detects

the pattern, the adaptation layer 116 in the originating gateway 100A is connected 300 to the DS0 circuit that is handling the call.

If the continuity check is successful, the gateway 100A also notifies 305 its call controller 120A that the pattern has been detected. The originating call controller 120A sends 310 an SS7 message to the terminating call controller 120B informing it of the successful continuity check. In response, the call controller 120B instructs the terminating gateway 100B to disconnect 315 the loopback between the incoming and outgoing packet streams. The terminating gateway 100B is then reconfigured 320 to continue processing the call.

Continuity check packets also can be used as a coarse determination of the Cell Delay Variation in the packet network. In that case, the pattern of bits should be sent over at least several cells.

The foregoing continuity check operations can be used in systems employing ``robbed'' bit supervisory signaling as well as clear channel operation. However, when the continuity check packets are used in a system employing ``robbed'' bit supervisory signaling, the fact that the low order bits of some frames are used for the supervisory signaling should be accounted for. For example, the bits that are used for supervisory signaling can simply be ignored for the purpose of the continuity checks.

As described above, different call controllers 120A, 120B are associated with the gateways 100A, 100B. However, in some cases, both the originating and terminating gateways 100A, 100B may share a common call controller, such as the call controller 120A. In that case, a technique similar to that discussed above can be used with a single call controller performing the functions of both call controllers 120A, 120B. When the call controller 120A routes the call after receiving the IAM message 150, it selects the terminating TDM circuit switch and the corresponding terminating gateway 100B to handle the call. Also, when a single call controller 120A is involved, the IAM message 156 need not be used.

Although the foregoing implementations have been described with respect to ATM networks, circuit-switched traffic can be routed over other packet-domain networks, such as frame relay, Ethernet and Internet Protocol (IP) networks, as well.

Continuity check operations based on a pattern of digital bits are not limited to systems under the control of SS7 signaling. In addition, continuity checks can be performed independently of call set-up processes. For example, in some cases, the pattern generator 122 can continuously generate a pattern over an existing packet connection. The pattern detector 124 monitors the return signals and checks whether the specified pattern is detected. The output of the pattern detector 124 then can

be read on demand. Such testing can be used, for example, as part of a maintenance program to determine how often failures occur on a particular packet connection and its associated gateways.

5 For situations in which a gateway has multiple adapters for handling conversions between packet-based and TDM-based bearers, separate pattern generators 122 and pattern detectors 124 can be provided for each adapter. Alternatively, the specified pattern can be broadcast over
10 the multiple ATM channels and/or connections.

In some implementations, the timer 132 can be incorporated into the call controller 120A. In that case, the call controller 120A would determine that the continuity check had failed if the gateway 100A did not notify it that
15 the continuity check was successful within the specified time. Alternatively, the call controller 120A can be programmed to query the gateway 100A regarding the success of the continuity check if the gateway has not provided an indication prior to the specified time elapsing. The
20 success or failure of the continuity check would then be determined based on the gateway's response.

Various features of the system can be implemented in hardware, software, or a combination of hardware and software. For example, some aspects of the system can be
25 implemented in computer programs executing on programmable computers. Each program can be implemented in a high level procedural or object-oriented programming language to